Preloading Loss Estimation at The End Clamp

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Preloading to the cable is given by a collet end clamp in the end part of the magnet. The shrinkage of the insulator blocks may cause a significant loss of preloading. A finite element analysis was already made indicating that the loss of preloading is large if we use azimuthally fibered G10. I made an estimation of preloading loss using recently obtained thermal contraction rate of materials.

The pressure,q, given by the stainless steel cylinder changes with the change of inner diameter of the cylinder. This is calculated in the same way as a pressure vessel. Simply from the force balance in Fig.1,

$$q=sE(a-b)/b \qquad (1)$$

where, E is Young's modulus, s is strain, a and b are inner and outer radius of the cylinder, respectively. This is valid when the cylinder is thin. For more accurate expression, Roark's textbook gives:

$$q=sE(a**2-b**2)/(a**2+b**2+u(a**2-b**2)) \qquad (2)$$

where, u is the Poisson's ratio and normally about 0.3. From the geometry in Fig.2 and 3, equations (1) and (2) is evaluated using E=20000kg/mm2 as

	40 mm design	50 mm design
a	79.83	99.06
b	66.43	81.56
q(1)	4034*s	4291*s
q(2)	3446*s	3630*s

q(1) and q(2) are not much different but we use q(2) as better expression. The strain change due to the thermal contraction is given by the balance of cylinder shrinkage,sc, insulator block shrinkage,sb and magnet coil shrinkage,sm.

$$s=(sm*c + sb*(b-c) - sc*b)/b$$

$$=sm(c/b) -sc +sb*(1-(c/b)) \qquad (3)$$

where, c is the coil outer radius. The value for sc is 0.278% from the recent measurement. If we take sm=0.4% from the experience of DESY and also from the composition ratio of the coil, The recently measured thermal contraction values give the following strain changes.

	40 mm design	50 mm design
	c=20	c=25
	s=0.699sb-0.158%	s=0.693sb -0.155
G10// (sb=0.971%)	s=0.520%	s=0.517%
stycast(sb=0.485%)	s=0.181%	s=0.181%
G10 T (sb=0.139%)	s=-0.06%	s=-0.058%
steel (sb=0.2 %)	s=-0.018%	s=-0.027%

The coil has more G10 parts in the end ,but since they are reinforced in azimuthal direction, they do not contribute to increase the contraction. Therefore, the pressure loss are given as follows using q(2):

	40 mm design	50 mm design
G10 //	17.92	18.77
stycast	6.23	6.57
G10 T	-2.06	-2.11
steel	-0.62	-0.98

If these pressures are converted into the azimuthal stress in the coil, the conversion factor is about 1. This means if we use G10, preloading is completely lost during cooldown. Even stycast will loose significant amount of preloading. On the other hand, the use of radially reinforced G10 will gain the preloading. The use of steel will keep the pressure with a slight enhancement.

To decrease the thermal contraction of stycast, we could increse the content of filler. But in this case, the material becomes harder like putty and it will become difficult to be poured in a die. One solution for this may be to use Mn-steel and covering the surface by epoxy putty as shown in Fig.4.

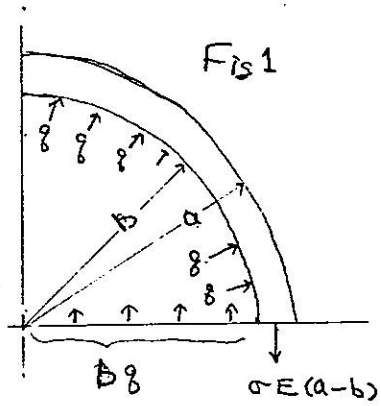


Fig 2. 40mm Design

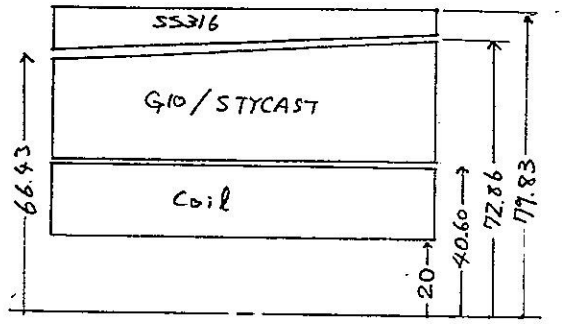


Fig 3. 50mm Design

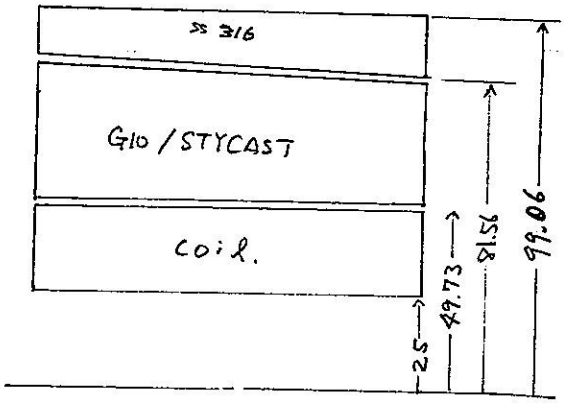
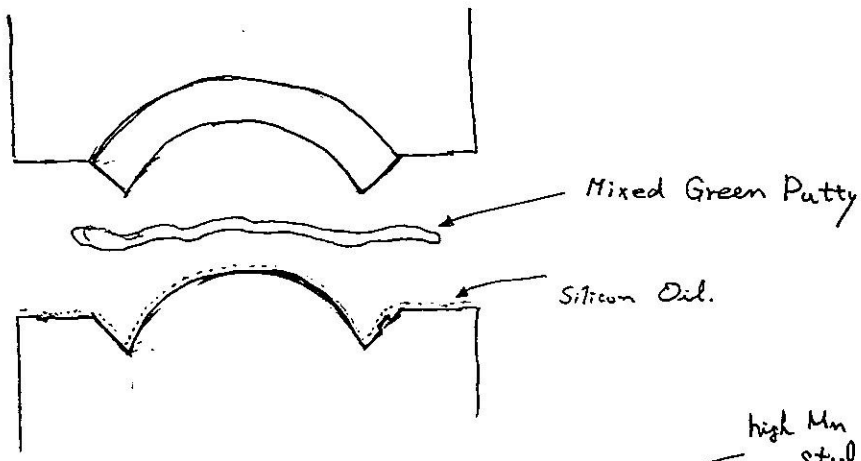
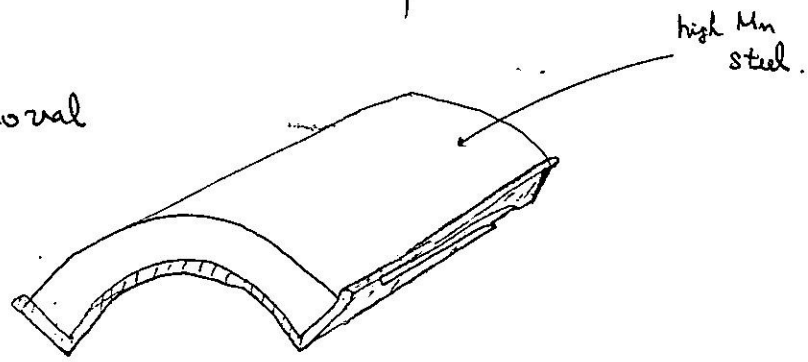


Fig 4. Use of iron + putty.

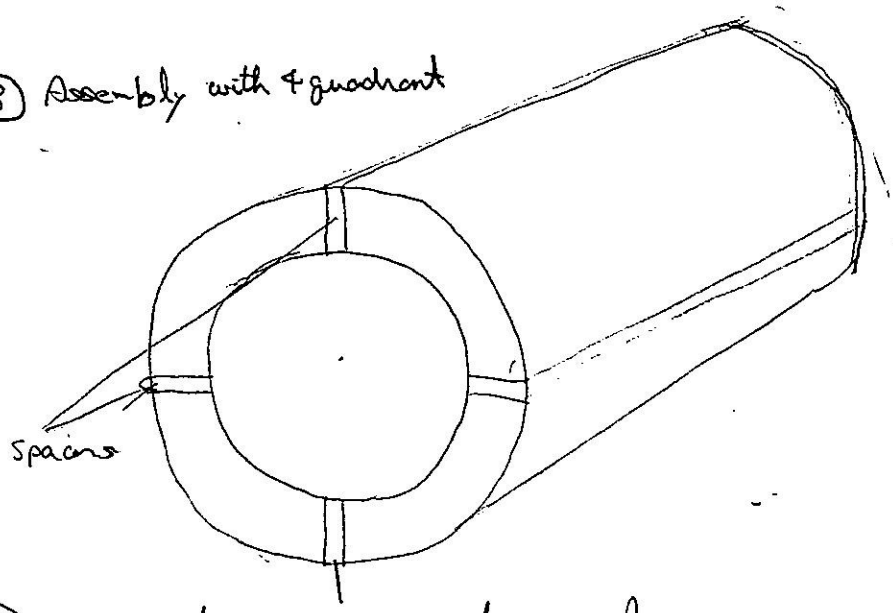
① Pressing and curing



② die - removal



③ Assembly with 4 quadrant



④ re-machining of outer surface.

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